Space Technology Research Grants

A Hybrid Systems Strategy to Support Autonomous Spacecraft Trajectory Design and Optimization in Multiple Dynamical Regimes

Completed Technology Project (2012 - 2015)

Project Introduction

With ever increasing numbers of near-Earth satellites and deep space missions, autonomous spacecraft guidance, navigation, and control (GNC) systems are increasingly attractive as a method both to reduce the cost of ground operations and to enable mission scenarios beyond Earths neighborhood. Additionally, self-reliant GNC systems possess the potential to reduce spacecraft response times where delays are introduced by communications lags and human-in-the-loop interactions. Autonomy is particularly important for deep space missions where there is significant response time delay and sporadic communication due to the physical distance between the spacecraft and Earth. A strategy that independently and adaptively handles the GNC requirements, from generating baseline trajectories to control about the reference path, in an effort to satisfy specified mission objectives is therefore highly desirable. The scope of the current problem is restricted to the generation and optimization of reference solutions for spacecraft trajectories. A strategy combining a multitude of gravitational models and propulsion methods, functional and direct optimization, and hybrid systems methodologies is proposed. Specifically, a method for the autonomous generation, selection, and optimization of reference spacecraft trajectories in multiple gravitational regimes will be developed. The proposed trajectory design and optimization scheme is sufficiently general to allow for wide implementation among a variety of spacecraft and scenarios. The methodology will be autonomous and adaptable such that baseline solutions are generated numerically and, when necessary, re-designed with a minimum of human-in-the-loop interaction. The procedure will independently determine an appropriate gravitational model for reference trajectory design and controller/estimator operation based on navigational data. Hybrid systems theory is implemented to specify a sequence of dynamical regimes that will satisfy mission objectives. Therefore, a baseline design for a mission from Earth to Europa, for example, could include propagations in Earth, Sun-Earth, Sun, Sun-Jupiter, and Jupiter-Europa gravitational models with low-thrust engine operation and impulsive maneuvers during varying segments along the full trajectory. Reference trajectories, comprised of impulsive maneuvers and/or low-thrust arcs, are optimized using a combination of functional and parameter optimization strategies. The underlying targeting process is inherently numerical, for example a shooting or collocation scheme, because of the non-linearity of the gravitational models and the likely inclusion of some type of continuous thrust or forcing effects. The primary investigation method will be numerical simulation of the autonomous scheme and its components. Because the purpose of this investigation is the development of the autonomous strategy, emphasis will be placed on robust operation rather than performance-optimized for a particular computing platform. Sample controllers/estimators will be included to test the operation of the overall design strategy, but the actual operation of the guidance and navigation system is not a focus of this research. Whether the objective is preliminary design or operations, the end goal is a process such that a desired spacecraft

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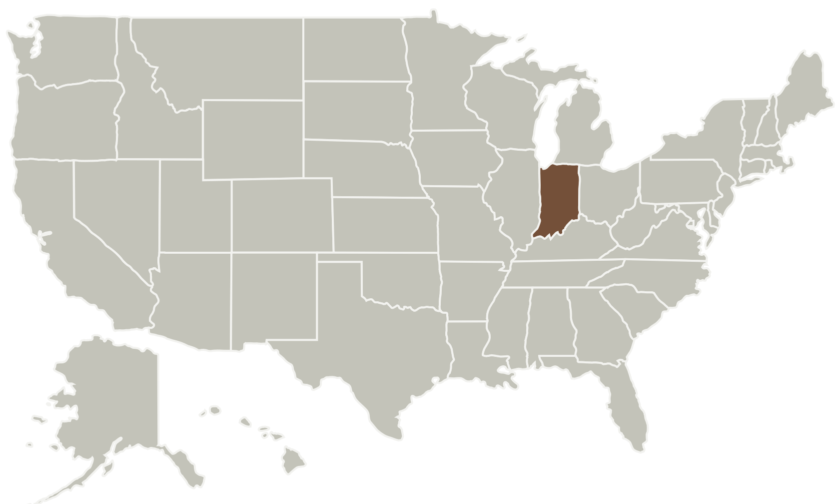
end-state and an allowable range of mission parameters are initially defined and a new design for the spacecraft path then emerges independently with an optimal series of maneuvers and/or low-thrust intervals to generate the desired response of the vehicle. The proposed strategy will extend the mission design and operation capabilities of future near-Earth and deep space NASA missions as well as increase engineering knowledge of autonomy and system optimization and design.

Anticipated Benefits

The proposed strategy will extend the mission design and operation capabilities of future near-Earth and deep space NASA missions as well as increase engineering knowledge of autonomy and system optimization and design.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Purdue University-Main Campus	Supporting Organization	Academia	West Lafayette, Indiana

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

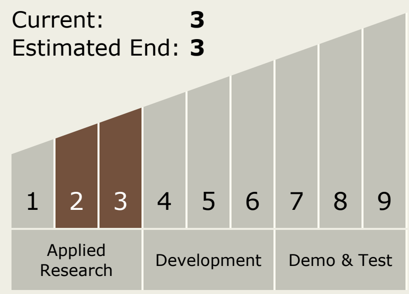
Kathleen M Howell

Co-Investigator:

Jeffrey Stuart

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Primary U.S. Work Locations

Indiana

Images

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Project Image A Hybrid Systems Strategy to Support Autonomous Spacecraft Trajectory Design and Optimization in Multiple Dynamical Regimes
(https://techport.nasa.gov/image/1712)

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Technology Areas

Primary:

- TX17 Guidance, Navigation, and Control (GN&C)
  └ TX17.2 Navigation Technologies
    └ TX17.2.6 Rendezvous, Proximity Operations, and Capture Trajectory Design and Orbit Determination